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for

Resolving Link Frame Collisions for a Phone Line Network

by

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Field of Invention

The present invention is directed to network communications, and more specifically, to the transmission of link frames over a home phone line network.

Background

The Home Phoneline Networking Alliance (HomePNA) is an incorporated, non-profit association of companies working to bring networking technology to the home. See www.homepna.org. HomePNA envisions bringing Ethernet technology to the home by utilizing existing home phone wiring for the network physical medium. HomePNA provides specifications for the physical layer (PHY), its interface to an Ethernet MAC (Media Access Control), and its interface to the home phone wiring. See the IEEE (Institute of Electrical and Electronic Engineers) 802.3 standard for Ethernet.

The position of a HomePNA PHY in relationship to the OSI (Open Systems Interconnection) model is illustrated in Fig. 1. Logical Link Control (LLC) **102** and MAC **104** are implemented in accordance with IEEE 802.3, and HomePNA PHY **106** communicates with MAC **104** via interface **108**. Additional sublayers, and other optional layers, may be added to the layers shown in Fig. 1 so that PHY **106** may provide services to other communication protocols, such as Gigabit Ethernet. In practice, PHY **106** and MAC **104** may be integrated on a single die, so that interface **108** is not readily visible.

PHY **106** receives a MAC frame from MAC **104**, strips off the 8 octets of preamble and delimiter from the MAC frame, adds a HomePNA PHY header to form a HomePNA PHY frame, and transmits a PHY frame on physical medium **110**. Fig. 2 illustrates HomePNA PHY framing. A PHY frame comprises Ethernet Packet **202**, and appended to Ethernet Packet **202** is a HomePNA PHY header, comprising SYNC interval **204**, Access ID (Identification) **206**, Silence interval **208**, and PCOM field **210**.

A PHY frame is transmitted on physical medium **110** utilizing pulse position modulation (PPM). All PHY symbols transmitted on physical medium **110** comprise a pulse formed of an integer number of cycles of a square wave that has been filtered with a bandpass filter. The position of the pulse conveys the transmitted symbol. Differential signaling is employed, in which a pulse and its negative are transmitted on two wires for each transmitted symbol.

As indicated in Fig. 2, transmission begins with SYNC symbol 0, and Access ID field **206** is coded into seven AID (Access ID) symbols. SYNC symbol 0 may also be denoted as AID symbol 0. Access ID symbols 1 through 4 are used to identify individual stations to enable reliable collision detection. Access ID symbols 5 and 6 are used to transmit remote control management commands. AID symbol 7 is a silence interval.

SYNC symbol 0 and each AID symbol are 129 tics long, where 1 tic is defined as $(7/60)10^{-6}$ seconds, which is approximately 116.667 nanoseconds. AID symbols 1 through 7 begin with a blanking interval of 60 tics, followed by a pulse positioned within one of four time slots to convey two bits of information. The time slots are separated by 20 tics, and are at positions 66, 86, 106, and 126 tics from the beginning of an AID symbol interval. SYNC symbol 0 is composed of a SYNC_START pulse beginning at tic = 0 and a SYNC_END pulse beginning at tic = 126.

In the example of Fig. 2, AID symbols 1 through 4 represent the Access ID word 00101101, where AID symbol 1 represents AID0 = 1 and AID1 = 0, AID symbol 2 represents AID2 = 1 and AID3 = 1, AID symbol 3 represents AID4 = 0 and AID5 = 1, and AID symbol 4 represents AID6 = 0 and AID7 = 0. AID symbols 5 and 6 represent the control word 0001, where AID symbol 5 represents Ctrl0 = 1 and Ctrl1 = 0, and AID symbol 7 represents Ctrl2 = 0 and Ctrl3 = 0.

A collision is detected only during AID symbols 0 through 7. If a transmitting station reads back an AID value that does not match its own, then a collision is indicated, and a JAM signal is transmitted to alert other stations. Non-transmitting stations may also detect non-conforming AID pulses as collisions. Only a transmitting station emits a JAM signal.

Fig. 3 illustrates in more detail MAC-to-HomePNA PHY interface **108**. The signals RxD, RxClk, TxD, TxClk, TxEn, CRS, and COL are described in Table 1. HomePNA PHY **106** retains control of the TxClk and RxClk signals for clocking data synchronously in and out of MAC **104**.

Table 1 HomePNA PHY-to-MAC Interface Signals.

MAC Interface Signal	Output From	Function
RxD	PHY	Data to the MAC is synchronously clocked by RX_CLK

MAC Interface Signal	Output From	Function
RxClk	PHY	Clock for RX_DATA
TxD	MAC	Data to the PHY is synchronously clocked by TX_CLK
TxClk	PHY	Clock for TX_DATA
TxEN	MAC	Transmit enable request from the MAC to begin sending data to the PHY.
CRS	PHY	Carrier Sense indicates the PHY is receiving a valid signal from the wiring network
COL	PHY	Collision. Indicates a collision was detected by the PHY on the wiring network

Devices connected to the network have the ability to detect whether they are connected to a "live" network or not by means of a valid link indication function. HomePNA PHY **106** provides a valid link indication via signal Valid Link **302**. Valid Link signal **302** may be provided to other layers or a management entity, and indicates whether link **110** is determined by PHY **106** to be functioning.

Each PHY on the network transmits a link frame if it has not transmitted a normal data frame or link frame for 2.0 seconds. The reception of a normal data PHY frame or a link frame causes a valid link indication. Non reception of data or link frames within a time period of not less than 4.0 seconds causes Valid Link signal **302** to indicate an invalid link indication.

Link frames are obtained from link packets by appending a HomePNA header as described in reference to Fig. 2. Link packets are defined by the HomePNA to be either runt packets, null-addressed packets, or self-addressed packets. Runt packets are less than 64 bytes in length. The HomePNA recommends that link packets be implemented as indicated in Table 2.

Table 2. Link Packets

Option 1: Runt Packet (14 bytes)

Field	Length	Description
Destination Address	6 bytes	The Destination address is either a NULL address (all zeros), or the originating station's MAC address.
Source Address	6 bytes	The Source address is either a NULL address (all zeroes), or the originating station's MAC address
Type/Length	2 bytes	The type/length field is set to a byte sequence value of 00-01 (hex). This value is an illegal length (not a type) that allows a promiscuous mode sniffer to determine that the runt is a HomePNA link frame.

Option 2: Minimum Sized Packet (64 bytes)

Field	Length	Description
Destination Address	6 bytes	The Destination address is either a NULL (all zeros), or the originating station's MAC address.
Source Address	6 bytes	The Source address is either a NULL address (all zeroes), or the originating station's MAC address
Type/Length	2 bytes	The Type/Length field is set to a byte sequence value of 00-2E (hex). This is a valid LLC length of 46 bytes.
LLC Test PDU Header	3 bytes	The DSAP field is set to a byte sequence value of 00-00-F3 (hex). This indicates a null-DSAP LLC test request frame.
Data	43 bytes	The data area of the link frame contains the following null terminated string: "HomePNA (version 1.1) Link heartbeat frame" This string allows promiscuous mode sniffers to determine that the frame is a HomePNA link frame.
CRC	4 bytes	Valid MAC CRC

Usually, the transmission of frames by a PHY requires a MAC layer. But for various market-demand reasons, it is desirable for a PHY to provide valid link indication functionality without assistance from a MAC or higher layer. This allows the use of Ethernet MAC chips that may not have valid link indication functionality built-in, and does not require the need to implement valid link indication functionality in software. The latter is important, not only because implementing valid link indication functionality in software may slow down system performance, but also because there may be power-saving states in which software will not work but for which link indication functionality is still needed. However, the requirement to have MAC functionality incorporated in a PHY is costly and leads to redundancy in devices that also have a MAC layer. It is therefore desirable for a PHY to have valid link indication functionality without the overhead of a MAC layer. There is also a need for a PHY to efficiently handle collisions between a link frame and a data frame, and between a link frame and another link frame. The present invention addresses these issues.

Brief Description of the Drawings

Fig. 1 illustrates the position of a HomePNA PHY within the OSI communication protocol stack.

Fig. 2 illustrates HomePNA PHY framing.

Fig. 3 illustrates a MAC-to-HomePNA PHY interface.

Fig. 4 provides a flow diagram for an embodiment of the present invention.

Fig. 5 provides a portion of the PHY architecture for an embodiment of the present invention.

Description of Embodiments

Fig. 4 diagrams a method implemented by a HomePNA PHY according to an embodiment of the present invention. In Fig. 4, step **402** tests for whether a frame has been transmitted for the last 2.0 seconds. If no transmission has occurred in the last 2.0 seconds, then in step **404** the TxClk signal is stopped so that MAC **104** does not request PHY **106** to transmit a MAC frame, and a link frame is transmitted.

During transmission of the link frame in step **404**, step **406** determines whether a collision is detected. If no collision is detected during transmission of the link frame, then the TxClk signal is enabled in step **407** so that MAC **104** is enabled to request transmission of MAC frames, and control is brought back to step **402**. If a collision is detected, then a counter for keeping track of the number of collisions, referred to as Num_Col, is set to zero in step **408**, and control is brought to step **410**.

In step **410** the link frame is re-transmitted after waiting an interval of time equal to IPG, the minimum Inter Packet Gap. Step **412** determines whether a collision is detected during re-transmission of the link frame. If there is no collision, then the TxClk signal is enabled in step **407** and control is brought back to step **402**. If there is a collision, control is brought to step **414**, whereupon the counter Num_Col is incremented by one.

After Num_Col is incremented by one in step **414**, step **416** determines whether it is less than a positive integer N. If Num_Col is less than N, control is brought back to step **410**, whereupon the link frame is again re-transmitted after waiting an IPG. If, however, Num_Col is no longer less than N in step **416**, then control is brought to step **417** rather than looping back to step **410**.

The loop defined by steps **410**, **412**, **414**, and **416** causes a colliding link frame to be re-transmitted, with each re-transmission separated by an IPG, until either a collision-free link frame transmission has been accomplished, or until N re-transmissions have been made. Thus, counting the initial link frame transmission in step **404**, when a link frame collides with another frame from another PHY, a sequence of back-to-back link

frames, each separated by an IPG, will be transmitted, up to a maximum number of N+1 link frames. The integer N may be distinct for each HomePNA PHY, or may be the same for all HomePNA PHYs.

Once the number of re-transmissions for a colliding link frame has reached N (Num_Col is no longer less than N in step **416**), the TxClk signal is enabled in step **417** so that MAC **104** may request PHY **106** to transmit a MAC frame, and a random time interval is allowed to elapse in step **418** before control is brought back to step **402**. The randomization provided in step **418** prevents a live-lock condition in which two colliding PHYs are each attempting to transmit a link frame.

Because step **410** re-transmits a colliding link frame after waiting only for an IPG, re-transmission of a colliding link frame is given higher priority than the re-transmission of a colliding data frame governed by the random process used for Ethernet, known as the truncated binary exponential backoff.

Fig. 5 provides a portion of the PHY architecture for an embodiment of the present invention. Finite state machine (FSM) **502** implements the flow diagram of Fig. 4. For simplicity, only the TxClk signal and Valid Link signal **302** are shown in Fig. 5. Counter **514** stores the value of Num_Col as described in reference to Fig. 4. Collision detector **504** indicates to FSM **502** whether a collision is detected, and FSM **502** indicates to transceiver **512** when a link packet is to be transmitted according to the flow diagram of Fig. 4.

The random time interval generated in step **418** of Fig. 4 may be realized in Fig. 5 by ring oscillator **506**, free-running counter **508**, and latch **510**. Ring oscillator **506** provides a clock signal to free-running counter **508**, and is designed so that its frequency, and hence the clock signal used to clock counter **508**, is a function of temperature, process, or other environmental factors. Counter **508** is sampled and latched by latch **510** to provide a random number. FSM **502** uses the random number stored in latch **510** to determine the random time interval in step **418**.

FSM **502** may be realized by a programmable logic device, or an application specific integrated circuit. FMS **502** may also be realized by a programmable processor responsive to instructions stored as software or firmware. Various modifications may be made to the described embodiments without departing from the scope of the invention as

claimed below. For example, another embodiment may follow the flow diagram in Fig. 4, with the exception that if step **416** is answered in the negative, step **417** is not implemented, and after step **418**, Num_Col is re-set to zero and control is brought immediately to step **410** rather than to step **402**. In another embodiment, a time interval other than IPG may be used in step **410**. For example, a positive random variable may be added to IPG before re-transmitting a link frame in step **410**, so that a collision among colliding link frames may be more quickly resolved. However, such an approach may not give maximum priority to link frame re-transmission.